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DEPARTMENT OF ASTRONOMY

DEPARTMENT OF ELECTRICAL ENGINEERING

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INVESTIGATION OF GALACTIC AND PLANETARY RADIO ASTRONOMY

Status Report
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NASA Grant NSG 572

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The University of Michigan
Radio Astronomy Observatory

Department of Astronomy
Department of Electrical Engineering

STATUS REPORT

NASA GRANT

INTRODUCTION

This is the second semi-annual status report on NSG-572, initiated in October 1963.

NSG-572 is a three year, step-funded grant which continues investigation previously carried on under NASw-54 and NSG-181-61.

The organization of the following sections reflect the two tasks of the grant (I) Galactic Radio Astronomy and (II) Planetary Radio Astronomy Investigation.

I. Galactic Radio Astronomy

A. 11.03 Preparations

The principal effort of this period has been the engineering and scientific preparations for the scheduled 11.03 (Journeyman) launch.

1. Construction Progress

This was a fruitful period for the 11.03 Rocket Program. It began with the arrival of all remaining components and ended with a fully wired payload.

Construction of the following all new electronic packages was completed and the units were individually checked out: The antenna Z (impedance) switch box, the antenna Z oscillator-sweep chassis, the -23V regulator, VCO calibrator, filament preregulator, mainboard complex, power turn on Ledexes, +9V regulator, VCO chassis, +6.3V regulator, preamplifier, and remote control box.

The electrical rebuilding and checkout of the following carry over units from the 11.02 program was completed: New tubes were installed in the three receivers, the AGC characteristics were tailored and the gains set. The second stage preamplifier tubes were changed. The timer circuit was modified to produce the new flight sequence and supply a computer control voltage. The DC to DC converter, the preregulator, the +130V and +200V regulators were checked out under load.

The following items of a mechanical nature were completed: Construction and mounting of the battery box, construction of the antenna mounts, antenna length sensor design and construction, balancing of "C" and "E" decks, mechanical integration of all units into the payload structure, a flight level vibration test of "E" deck, the battery box and the antenna Z circuits at Bendix Systems, and modification of DeHavilland antennas to accommodate the larger motor.

The following subsystems were operated and checked out: solar aspect sensor, Langmuir probe, magnetometer, transmitter, commutator.

The flight batteries were charged, checked and selected.

A wiring list was prepared for all payload interconnect wiring. The interconnect wiring harness was constructed, installed and checked out with an ohmmeter. The payload is now complete and ready for the electrical checkout.

2. Systems Considerations and Problem Areas

Work continued in this period on the antenna dynamics problem. An outside consultant concluded on the basis of bending moments that we would be safe in deploying the 60-foot antennas at 3 inches per second. This problem is still not considered resolved.

Several meetings were held with the data processing group to make known our reduction requirements. A detailed plan will be drawn up as a working guide to serve both groups.

A flight plan was prepared and sent to Mr. John Guidotti at Goddard.

3. Projection for the Next Period

The payload will be checked out electrically and debugged where necessary. System performance will be measured.

A salt mine test will be conducted to locate any self-generated interference.

The complete payload will be calibrated.

The payload will be delivered to Goddard for T and E.

The launch will occur late in the period.

B. Radio Astronomy Satellite Study

A second major area during this period has been various studies in conjunction with a radio astronomy satellite specially designed for low frequency radio astronomy observations with high directivity. Studies continue on the electrical and mechanical problems of a large antenna and various approaches to the scientific, technical and management problems continue to be explored. We expect to complete a proposal to NASA on this concept early in 1965.

The status of our present thinking is as follows:

1. Principal Scientific Objectives

At frequencies near 1 Mc/s measure: (1) the flux density of several dozen extragalactic and galactic radio sources, (2) the statistical parameters of the receivers output variations due to variations in cosmic background level, (3) the cosmic background intensity contours, (4) the variations of radio emission from solar system objects and other sources, such as flare stars.

2. Operational Requirements

a. Narrow Beam Pattern - beam area of 80 square degrees is expected by using a large rhombic antenna (8.7 km overall length) combined with a dipole-array interferometer. This compound system has high angular resolution (about one degree) in a multilobe pattern.

b. Orbit - Preliminary study indicates that an orbit of slight eccentricity with apogee of approximately 60,000 miles is preferred.

c. Stabilization and Pointing - Spin stabilized with axis of rotation normal to antenna beam. Gravity gradient precession of the orbit may be adequate to scan the sky.

d. Sensitivity - Adequate receiver sensitivity in this frequency range is already proven by present flight payloads since the noise level is determined by cosmic background emission.

3. Tentative Configuration - Rhombic - Interferometer Compound System

Estimated system weight 5,000 to 10,000 pounds.

Length - rhombic 4.5 km per leg, maximum size 8.7 km compound multi-dipole linear array interferometer at right angles to axis of rhombic, also 8.7 km long.

II. Planetary Radio Astronomy Investigations

A. Photochemical studies

A critical study was made of the physical properties of selected gases of probable importance in planetary atmospheres, including compounds of carbon, oxygen, nitrogen, hydrogen and free radicals like OH and C_2O. Tables of heats of formation, bond strengths, and energies of photoionization and attachment were prepared as a draft report. A similar tabulation is planned for reaction energies and rate coefficients.

B. Magnetospheric studies

The latest information on the structure of the earth's exosphere, magnetosphere and the shock region beyond the magnetosphere, including analyses of whistlers, was compiled and used to draw a model daytime equatorial electron density profile out to 20 earth radii. Alouette topside profiles were used in this model. Essentially, the model begins with the Alouette sounding to 1000 km, and continues with a smooth transition to a -3.2 power law in the whistler region, to 4.5 earth radii, thence being proportional to the geomagnetic field strength to the magnetopause. Solar wind electron densities were assumed as 5 cm^{-3} (quiet) and 20 cm^{-3} (disturbed) for this phase of the sunspot cycle. Reports were written summarizing the above model, and indicating the correlation of the whistler and Alouetta data.

C. Electron distributions with arbitrary electron temperature

The complex distribution function for diffusive equilibrium in an atmosphere where the ion and electron temperatures are an arbitrary function of height has been reduced to a closed form involving one integral which involves the variation of the arbitrary ratio of ion to electron temperatures with height. One of two alternative forms of this integral may be used, depending on whether it is more convenient to work with a modified slope of the basic ion temperature distribution or with the logarithm of the distribution itself. This integral is the same for electrons and each ionic species. Thus the asymptote method of drawing the resultant ion distribution may be used, just as for the simplest isothermal distribution. A draft has been written of a report on this work. Following computation of a numerical example for illustration, it will be submitted for publication.

D. Lunar ionosphere studies

The results of ray-tracing computations using the Weil-Barasch lunar ionosphere model finally became available, and it is now possible to state the gross nature of radio propagation at or near the surface of the moon in the presence of this type of ionosphere. The main features distinguishing this model from the terrestrial ionosphere are a finite electron density at the surface and a very small electron density gradient at all heights, four orders of magnitude less than in the lower terrestrial E region.

Geometrical ray treatment of the propagation between surface stations leads to the following features:

1. Below the surface plasma frequency (127 kc) there is no propagation from a surface based antenna.
2. Between the surface plasma frequency and the maximum plasma frequency (170 kc) there are two possible rays for each distance. These merge to form a caustic at certain maximum distance for

each frequency. This results in a certain "minimum usable frequency" for each distance. There is no analog of this on earth.

3. At and for about 0.5 kc above the maximum plasma frequency there are three rays for each distance, two of which will still form a caustic.
4. Between this frequency (170.5 kc) and the frequency for which the surface of the smooth moon appears "flat" (275 kc) there is but one ray. At the lower frequencies in this range, and particularly the greater distances, the propagation will be rather unstable.
5. Above 275 kc there is only a surface wave, with a range greatly extended over such a wave on an ionosphereless moon at the lower frequencies, caused by the refractive index gradient close to the surface. For frequencies higher than about 1 Mc the lunar ionosphere has no significant effect on surface-to-surface communications.

For signals approaching the moon from outside the ionosphere, e.g., radiation from a galactic radio source, the refraction will be negative (away from the moon) for a ray penetrating the ionosphere no more deeply than a critical level, somewhat below the electron density peak. This refraction will be a maximum for a ray just reaching the level of the peak. For rays penetrating below this peak the refraction becomes positive (toward the moon) and reaches a maximum for a ray just grazing the surface. For the assumed ionospheric model, the maximum total refraction would be 6° for 500 kc, 37° for 300 kc, and 90° for 279 kc.

This completes the lunar ionosphere study. As soon as feasible the paper will be completed and submitted for publication.

E. Ionization of a tenuous argon atmosphere

This kind of an atmosphere might exist on the moon, if it is not blown away by the solar wind. A brief study was made of the photoionization of such an atmosphere, assuming recombination at the lunar surface or the major mechanism for ion loss. If the mean free path for electrons is less than the scale height of ions and/or neutral particles, a weak maximum of electron density will occur at around 1.2 moon radii.

F. Input impedance of a dipole near the lunar surface

Since radio astronomy from the lunar surface is expected to involve low-frequency antennas electrically close to the surface of the moon, considerable effort was expended in studying available theory and data regarding the impedance of a horizontal electric dipole near the moon's surface. In particular, it was desired to obtain a means of rapidly estimating the input resistance and reactance as a function of the free space parameters, the electrical constants of the lunar surface and the dipole height above the surface. For an electrical height of less than 0.5 radian above the surface, the following expression seems to fit the data and theory reasonably well:

$$\frac{\Delta Z}{R_o} = f(h, \epsilon_r) + j \frac{2}{3p^3} \frac{\bar{\epsilon}_r - 1}{\bar{\epsilon}_r + 1}$$

where ΔZ is the increment of impedance over the free space value

R_o is the free space radiation resistance

p is twice the electrical height of the dipole

$\bar{\epsilon}_r$ is the complex dielectric constant of the surface

ϵ_r is the real part of $\bar{\epsilon}_r$

$f(h, \epsilon_r)$ is a function of heights and ϵ_r that can be obtained by use of a nomogram.

A report on this work is in preparation.

III. PUBLICATIONS, PAPERS AND REPORTS

1. Schulte, H. F., Estry, H. W., Miller, R. L., Kuiper, J. W., "Instrumentation for Measurement of Cosmic Noise at 0.75, 1.225 and 2.0 Mc/s From A Rocket", University of Michigan Radio Astronomy Observatory Technical Report No. 64-15, 1964.

2. D. Walsh and F. T. Haddock, "Antenna Impedance in a Plasma: Problems Relevant to Radio Astronomy Measurements from Space Vehicles", Annales d'Astrophysique, Vol. 28, (3), 1965.

3. Walsh, D., "The Theory of Antennas in Plasmas: Its Role in Space Radio Astronomy and Relevant Work at UM/RAO", University of Michigan Radio Astronomy Observatory Technical Report No. 64-16, 1964.

4. Malville, J. M., "Ionization of N_2 in the Upper Atmosphere by Geomagnetically Trapped Electrons", J. of Geophys. Research, Vol. 69, No. 9, pp. 1831 - 1837, 1964.

5. Smith, N., "On the Equilibrium of Monatomic and Diatomic Helium ions", University of Michigan Radio Astronomy Observatory Technical Report No. 64-13, 1964.